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Claims

[c1] 1. A diffractive modulating element for modulating and diffracting an incident wave, comprising

a) a first plate assembly, the first plate assembly comprising a first zone plate with a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave;

b) a second plate assembly, the second plate assembly comprising a second reflective zone plate complementary to said first zone plate, the second plate assembly being positioned substantially parallel to said first plate assembly, and the second plate assembly receiving the incident wave after the first plate assembly;

c) displacing means for changing the relative distance between the first and second plate assemblies in a direction normal to the assemblies;

whereby the displacing means changes the relative distance between the first and second zone plates, and between a first configuration wherein the relative distance is $m/2$ times the wavelength of the incident wave, m is an integer number, the first and second zone plates act to reflect the incident wave as a plane mirror, and a second

configuration wherein the relative distance is $m/2 + 1/4$ times the wavelength of the incident wave, the first and second plates act to diffract the incident wave into a series of focal points along the axis of the zone plates as a phase zone plate.

[c2] 2. The element of claim 1, wherein said second plate assembly comprises a mirror.

[c3] 3. The element of claim 1, wherein the shape of the apertures of said first and second zone plates is substantially similar to the shape of said diffractive modulating element.

[c4] 4. The element of claim 1, wherein said incident wave is a wave selected from the group consisting of electromagnetic waves, matter waves, and acoustic waves.

[c5] 5. The element of claim 1, wherein one of the first and second plate assemblies is a movable plate assembly and the other is a stationary assembly, and further comprises a substrate and a first supporting means for supporting the movable plate assembly.

[c6] 6. The element of claim 5, wherein said displacing means comprises means for applying an electrostatic force generated by a voltage source to the movable plate assembly.

[c7] 7. The element of claim 5, wherein said first supporting means comprises a plurality of linkages, a plurality of deformable resilient beams, and a plurality of posts, whereby said linkages connect said movable plate assembly to said deformable resilient beams and said posts anchor said deformable resilient beams to said substrate.

[c8] 8. The element of claim 5, wherein said substrate comprises a semiconductor die having integrated circuits.

[c9] 9. The element of claim 7, wherein said movable plate assembly is said first plate assembly, and said stationary plate assembly is said second plate assembly affixed to said substrate.

[c10] 10. The element of claim 7, wherein said movable plate assembly is said second plate assembly, and said stationary plate assembly is said first zone plate assembly, and further comprises a second supporting means for supporting the stationary plate assembly above the movable plate assembly.

[c11] 11. The element of claim 10, wherein said second plate assembly further comprises a mechanical plate and a center post, said mechanical plate is connected to said deformable resilient beams through said linkages and

said second zone plate assembly is anchored onto said mechanical plate by said center post.

[c12] 12. The element of claim 5, wherein said substrate is a transparent substrate, and wherein said movable plate assembly is said second plate assembly and said stationary plate assembly is said first plate assembly and is affixed onto said transparent substrate, therefore the first plate assembly receives the incident wave from the transparent substrate side.

[c13] 13. The element of claim 12, further comprising a top cover structure, the top cover structure comprising a semiconductor substrate having integrated circuits and being coupled to said transparent substrate by an assembling means.

[c14] 14. A method of modulating an incident wave, comprising

a) forming a first plate assembly, the first plate assembly comprising a first zone plate with a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave;

b) forming a second plate assembly, the second plate assembly comprising a second reflective zone plate complementary to said first zone plate, the second plate assembly being positioned substantially parallel

to said first plate assembly, and the second plate assembly receiving the incident wave after the first plate assembly;

c) changing the relative distance between said first and second plate assemblies in a direction normal to the assemblies.

[c15] 15. A method of claim 14, wherein in a first configuration the relative distance between said first and second plate assemblies is $m/2$ times the wavelength of the incident wave, m is an integer number, the first and second zone plates act to reflect the incident wave as a plane mirror, and in a second configuration the relative distance is $m/2 + 1/4$ times the wavelength of the incident wave, the first and second zone plates act to diffract the incident wave into a series of focal points along the axis of the zone plates as a phase zone plate.

[c16] 16. A method of claim 14, wherein one of said plate assemblies is caused to move relative to the other by applying electrostatic forces to at least one of said plate assemblies.

[c17] 17. A diffractive modulating device, comprising a substrate and a plurality of regularly arranged individual diffractive modulating elements for modulating an incident wave, each of the diffractive modulating elements

comprising:

a) a first plate assembly, the first plate assembly comprising a first zone plate with a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave;

b) a second plate assembly, the second plate assembly comprising a second reflective zone plate complementary to said first zone plate, the second plate assembly being positioned substantially parallel to said first plate assembly, and the second plate assembly receiving the incident wave after the first plate assembly; and

c) displacing means for changing the relative distance between the first and second plate assemblies in a direction normal to the assemblies.

[c18] 18. The device of claim 17, wherein said second plate assembly of each diffractive modulating element comprises a mirror.

[c19] 19. The device of claim 17, wherein the shape of the apertures of said first and second zone plates of each diffractive modulating element is substantially similar to the shape of said diffractive modulating element.

[c20] 20. The device of claim 17, wherein said incident wave is a wave selected from the group consisting of electro-

magnetic waves, matter waves, and acoustic waves.

[c21] 21. The device of claim 17, wherein said substrate comprises a semiconductor die having integrated circuits.

[c22] 22. The device of claim 17, wherein one of the first and second plate assemblies of each diffractive modulating element is a movable plate assembly.

[c23] 23. The device of claim 22, wherein said displacing means of each diffractive modulating element comprises means for applying an electrostatic force generated by a voltage source to said movable plate assembly.

[c24] 24. The device of claim 22, wherein each diffractive element further comprising a supporting means for supporting the movable plate assembly.

[c25] 25. The device of claim 24, wherein said supporting means of each diffractive modulating elements comprises a plurality of linkages, a plurality of deformable resilient beams, and a plurality of posts, whereby the linkages connect said movable plate assembly to said deformable resilient beams and said posts anchor said deformable resilient beams to said substrate.

[c26] 26. The device of claim 22, wherein said substrate is a transparent substrate, and wherein said movable plate

assembly of each diffractive modulating element is said second plate assembly, and said stationary plate assembly of each diffractive modulating element is said first plate assembly and is affixed onto said transparent substrate, therefore the first plate assembly receives the incident wave from the transparent substrate side.

[c27] 27. The device of claim 26, further comprising a top cover structure, the top cover structure comprising a semiconductor die having integrated circuits and being coupled to said transparent substrate by an assembling means.

[c28] 28. The device of claim 17, wherein said diffractive modulating elements are arranged as an one-dimensional array.

[c29] 29. The device of claim 17, wherein said diffractive modulating elements are arranged as a two-dimensional array on a square grid.

[c30] 30. The device of claim 17, wherein said diffractive modulating elements are arranged as a staggered two-dimensional array, each row of said staggered two-dimensional array is shifted horizontally by a distance with respect to the previous row.

[c31] 31. An achromatic diffractive modulating element for

modulating and diffracting an incident wave, comprising

a) a reference surface, the reference surface including a portion of a first zone plate having a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave;

b) a deflecting surface, the deflecting surface including a second zone plate with a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave, the deflecting surface being substantially parallel to and substantially concentric with said reference surface;

c) a compensating surface, the compensating surface being reflective and providing a portion of the first zone plate, the compensating surface being substantially parallel to and substantially concentric with said reference surface, the reference surface and the compensating surface forming a complete first zone plate which is complementary to the second zone plate;

d) displacing means for moving the deflecting surface with respect to the reference and compensating surfaces in a direction normal to the surfaces.

[c32] 32. The element of claim 31, wherein in the un-deflected configuration said deflecting surface is positioned approximately $M\lambda/2$ below said reference surface and said

compensating surface is positioned approximately $N\lambda/2$ below said reference surface, where M and N are integers and λ is the center wavelength of the incident wave, and wherein the ratio Ac/Ad of the total reflective surface area Ac of the compensating surface to the total reflective surface area Ad of the deflecting surface is approximately equal to $(2M+1)/(2N)$, and wherein the sum of the total reflective surface area Ar of the reference surface and the total reflective surface area Ac of the compensating surface is approximately equal to the total reflective surface area Ad of the deflecting surface,
whereby in the un-deflected configuration, the waves reflected from all surfaces interfere constructively and said achromatic diffractive modulating element acts to reflect the incident wave as a plane mirror, and in a deflected configuration where the deflection is 1/4 of the center wavelength of the incident wave, the waves reflected from all surfaces cancel out each other and said achromatic diffractive modulating element acts to attenuate the incident wave irrelevant of the wavelength of the incident wave.

[c33] 33. The element of claim 31, wherein said incident wave is a wave selected from the group consisting of electromagnetic waves, matter waves, and acoustic waves.

[c34] 34. The element of claim 32 further comprises a substrate, a first supporting means and a second supporting means, wherein said compensating surface is affixed onto said substrate, said deflecting surface is a movable surface and is anchored onto the substrate by the first supporting means, and said reference surface is mounted onto the substrate by the second supporting means, whereby the deflecting surface is caused to move by the displacing means in a direction normal to the plane of the deflecting surface and with respect to the reference and compensating surfaces.

[c35] 35. The element of claim 34, wherein said first supporting means comprises a plurality of linkages, a plurality of deformable resilient beams, and a plurality of posts, whereby the linkages connect said deflecting surface to said deformable resilient beams and said posts anchor said deformable resilient beams to said substrate.

[c36] 36. The element of claim 34, wherein said movable surface further comprises a first electrode and said substrate comprising a second electrode, wherein said displacing means comprises means for applying an electrostatic force generated by a voltage source to the movable surface.

[c37] 37. The element of claim 34, wherein said value M is ap-

proximately equal to 1 and said value N is approximately equal to 3, and wherein said deflecting surface comprises the 2nd and 4th reflective zones with the 1st zone being a hole, and said reference surface comprises the 1st reflective zone as a center island directly situated on said substrate and through the center hole of the deflecting surface.

[c38] 38. A method for achromatic modulation of an incident wave, comprising

a) forming a reference surface, the reference surface including a portion of a first zone plate having a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave;

b) forming a deflecting surface, the deflecting surface including a second zone plate with a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave, the deflecting surface being substantially parallel to and substantially concentric with said reference surface;

c) forming a compensating surface, the compensating surface being reflective and providing a portion of the first zone plate, the compensating surface being substantially parallel to and substantially concentric with said reference surface, the reference surface and the compensating surface forming a complete

first zone plate which is complementary to the second zone plate;

d) moving the deflecting surface with respect to the reference and compensating surfaces in a direction normal to the surfaces.

[c39] 39. The method of claim 38, wherein in the un-deflected configuration said deflecting surface is positioned approximately $M\lambda/2$ below said reference surface and said compensating surface is positioned approximately $N\lambda/2$ below said reference surface, where M and N are integers and λ is the center wavelength of the incident wave, and wherein the ratio Ac/Ad of the total reflective surface area Ac of the compensating surface to the total reflective surface area Ad of the deflecting surface is approximately equal to $(2M+1)/(2N)$, and wherein the sum of the total reflective surface area Ar of the reference surface and the total reflective surface area Ac of the compensating surface is approximately equal to the total reflective surface area Ad of the deflecting surface.

[c40] 40. A method of claim 38, wherein said deflecting surface is caused to move relative to other surfaces by applying electrostatic forces to the deflecting surface.

[c41] 41. A controllable optical attenuating system for attenuating an optical beam, comprising

a) an input fiber, the input fiber having an endface and being responsible for coupling in an optical beam;

b) a lens system, the lens system being optically coupled to the input fiber and being capable of collimating the optical beam that exits the endface of the input fiber;

c) an output fiber, the output fiber being optically coupled to the lens system;

d) a diffractive modulating element, the diffractive modulating element being optically coupled to the lens system and being capable of reflecting substantially none to substantially all of the optical beam from the input optical fiber through the lens, back through the lens and into the output fiber, wherein said diffractive modulating element comprises

i) a reference surface, the reference surface including a portion of a first zone plate having a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave;

ii) a deflecting surface, the deflecting surface being a second zone plate with a set of alternate zones being reflective and the remaining zones being transmissive to the incident wave, the deflecting surface being substantially parallel to and substan-

tially concentric with said reference surface;

iii) a compensating surface, the compensating surface being reflective and providing a portion of the first zone plate, the compensating surface being substantially parallel to and substantially concentric with said reference surface, the reference surface and the compensating surface forming a complete first zone plate which is complementary to the second zone plate;

iv) displacing means for moving the deflecting surface with respect to the reference and the compensating surfaces a direction normal to the surfaces.

[c42] 42. The system of claim 41, wherein in the un-deflected configuration said deflecting surface of the diffractive modulating element is positioned approximately $M\lambda/2$ below said reference surface and said compensating surface is positioned below approximately $N\lambda/2$ below said reference surface, where M and N are integers and λ is the center wavelength of the incident wave, and wherein the ratio Ac/Ad of the total reflective surface area Ac of the compensating surface of the diffractive element, to the total reflective surface area Ad of the deflecting surface is approximately $(2M+1)/(2N)$, and wherein the sum of the total reflective surface area Ar of the reference

surface and the total reflective surface area Ac of the compensating surface is approximately equal to the total reflective surface area Ad of the deflecting surface.

[c43] 43. The system of claim 42, said diffractive modulating element further comprises a substrate, a first supporting means and a second supporting means, wherein said compensating surface is affixed onto said substrate, said deflecting surface is a movable surface and is anchored onto said substrate by said first supporting means, and said reference surface is mounted onto said substrate by said second supporting means, whereby the deflecting surface is caused to move by said displacing means in a direction normal to the plane of the deflecting surface and with respect to the reference and the compensating surfaces.

[c44] 44. The system of claim 43, wherein said first supporting means of said diffractive modulating element comprises a plurality of linkages, a plurality of deformable resilient beams, and a plurality of posts, whereby the linkages connect said deflecting surface to said deformable resilient beams and said posts anchor said deformable resilient beams to said substrate.

[c45] 45. The system of claim 42, wherein said deflecting surface of said diffractive modulating element further com-

prises a first electrode and said substrate comprising a second electrode, and wherein said displacing means comprises means for applying an electrostatic force generated by a voltage source to said deflecting surface.

[c46] 46. The system of claim 45, wherein said first electrode of said diffractive modulating element comprises a transparent conductive layer.

[c47] 47. The system of claim 41, further comprising a plurality of said diffractive modulating elements.